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Cold Start and Driveability of Vehicles Operating on Methanol- Gasoline Blends

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ENGINEERING DIVISION
Advanced Engine Technology Centre

COLD START AND DRIVEABILITY OF VEHICLES OPERATING ON METHANOL/GASOLINE BLENDS

Revised Final Report No. 5287
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1. INTRODUCTION

New volatility class characteristics for oxygenated gasolines are being proposed for consideration as a Canadian General Standards Board (CGSB) standard, separate from those of conventional gasolines. The new volatility classes contain RVP characteristics higher than permissible under current CGSB standards for gasoline.

The objective of the present study is therefore to assess the effectiveness of these new volatility classes, involving higher RVP's, on cold engine startability and driveability on methanol/gasoline blends.

The project was sponsored by the Canadian Oxygenated Fuel Association (COFA) and funded by Energy, Mines and Resources, Canada and the Ontario Ministry of Energy. The work was carried out jointly by the Ontario Research Foundation (ORF) and Esso Petroleum Canada (EPC). ORF managed the program and carried out a review of parallel programs to attempt to find some commonality and consistency in the results of fleet testing with the fuel specification, nature of the test program, etc., while EPC was responsible for carrying out controlled tests of cold driveability using the all weather chassis dynamometer located at EPC in Sarnia.

2. APPROACH

To initiate the program, ORF called a meeting to make a final selection of test fuels, cars, test temperatures, and other details. Participants at this meeting included representatives from the oil, automotive, and chemical industry, together with the governments of Ontario and Canada. Agreement was reached on selection of the test fuels, vehicles, and test protocol. It was decided to limit the variables on the test fuels to RVP variations alone, keeping all other parameters of T_{10} °C, T_{50} °C and T_{90} °C as constant as possible. In this way, the effect of RVP on cold engine driveability with the blends, would be clearer to establish. Since it was also recognized that high RVP fuels could contribute to vapour lock conditions, the test protocol was developed to include hot driveability tests at the maximum ambient temperature permitted for the volatility of the fuel blend.

In parallel with these laboratory tests, ORF assembled, disseminated, and reviewed a large volume of literature and reports on earlier fleet tests with the blends, to bring together a balanced perspective of parameters affecting cold driveability issues and relate them to the current test program carried out under controlled conditions.

A meeting was then called of the same group involved in the initial selection process, to review the results and arrive at a consensus of issues which might remain to be resolved. This report details the results of these activities.

3. TEST PROTOCOL

3.1 Test Fuels

Five fuels were blended for the test program, a reference gasoline and four oxygenated/gasoline blends. The formulations and properties of these fuels are given in Table 1. The ASTM-D 86 distillation curves are plotted in Figures 1 to 5.

The reference gasoline A was blended to match the RVP (101 kPa) and distillation points of a Class B gasoline as defined by the proposed CGSB volatility classification. Fuel B, containing 5% MeOH - 3% EtOH, has the same RVP as the reference. Fuels C and D contain the same oxygenate component but have RVPs of, respectively, 114 and 127 kPa. Fuel E is another high RVP blend that includes 4.5% MeOH - 4.5% IPA. RVP adjustments were made by varying the amounts of butanes and pentanes streams in the blends. The T_{10}, T_{50} and T_{90} boiling points of the oxygenate blends were kept as close as possible to those of the reference gasoline so that RVP was the only key variable. To achieve this, the amount of one of the hydrocarbon components in the blends was varied.

Since the low-temperature volatilities of the fuels are of interest, the Reid Vapour Pressure (RVP) apparatus was used to measure the "RVP" of the fuels at several lower temperatures, as well as the standard temperature, 100°F (37.8°C). These data are given in Table 2 and plotted in Figure 6.

It can be seen that although the methanol blend B has the same RVP (at 37.8°C) as the conventional gasoline, the oxygenate blend has lower vapour pressure at lower temperatures. The other oxygenated blends which have much higher RVPs than the reference gasoline, have only slightly different vapour pressures at the lower temperatures.

3.2 Test Vehicles

Three popular engines, one each from GM, Ford and Chrysler were selected for this test. These were the GM 2.8 litre V6, the Ford 1.6 litre OHV4 and the Chrysler 2.2 litre OHV4. The details of the test vehicles containing these engines are given in Table 3.

3.3 Cold-Start and Driveability Test at -20°C

Each vehicle and fuel combination was tested at -20°C as follows:

Run 1

The vehicle was cold soaked overnight at -20°C for 12 hours. The vehicle was then subjected to the driving cycle described in Appendix I, and rated using the rating procedure (Appendix II) and the rating form (Appendix III). The total cold-start and driveability demerits were recorded. The engine was shut off and allowed to stand until the maximum underhood temperature was reached (20-45 minutes). At this time, a restart of the vehicle was attempted.

Run 2

After the restart attempt, the vehicle was allowed to cool naturally for 1 1/2 hours, and then fan-cooled for a further 4 1/2 hours. At this time, the above drive cycle and rating procedure were repeated.

The rating of the car's performance on a test gasoline was done each time by the same two trained technologists sitting in the back seat of the automobile. The driver had the best "feel" of the car for hesitation during rapid acceleration and indicated to the raters that a demerit should be given. The two raters did not communicate with each other and the final rating was the average of their individual ratings.

3.4 Hot Driveability Test at 15°C

The GM Celebrity and the Ford Escort were tested at 15°C with each of the five fuels using the procedure described in Appendix IV.

4. RESULTS

The overall results (total weighted demerits for each run) of the cold-start and driveability test are given in Table 4. The breakdown of the demerit ratings for each run are given in Appendix V.

Table 5 lists the pre-test temperatures of the oil in the sump, the engine coolant and the carburettor bowl.

The results of the hot driveability testing are given in Table 6, while Table 7 shows a comparison of the temperatures of the oil sump, the carburettor and the engine block, before and after soaking with a tarpaulin on the hood.

5. CONCLUSIONS ON COLD AND HOT DRIVEABILITY TESTING

5.1 Vehicle A is insensitive to changes in fuel volatility at -20°C and performs well on all of them. At 15°C the vehicle exhibits driveability problems with all fuels. Vapour lock, as measured by the increase in acceleration times, is evident with fuels D, E, the very high vapour pressure fuels. Fuels A., B and C behave similarly in terms of providing vapour lock protection.

5.2 Vehicle B shows increased demerits with the oxygenated blend having the same RVP as the base gasoline and a trend to better performance with the higher RVP oxygenated gasolines at the -20°C temperatures. At 15°C fuels A, B, and C performed similarly in providing vapour lock protection. Fuel D, and to a lesser extent Fuel E, exhibited some indication of vapour lock.

5.3 Vehicle C runs relatively poorly on all fuels at -20°C although there is a tendency for improved performance with the higher RVP oxygenated gasolines as was also found with Vehicle B.

5.4 Overall

Vehicles B and C showed significant reduction in cold weather driveability when operated on an oxygenated gasoline with the same RVP as the base gasoline. Both vehicles showed improvement in driveability when the RVP of the fuel was increased. Fuel E, one of the highest RVP oxygenated gasolines, showed similar cold driveability to the base gasoline.

Fuels A, B, and C which have the lowest Vapour Lock Index exhibited similar protection against vapour lock in Vehicles A and B. Fuels D and E which exceed the Vapour Lock Index of the proposed CGSB Specification, showed some tendency towards vapour lock at the 15°C test temperatures.

6. REVIEW OF PAST FLEET TEST RESULTS

The objective of the review was to disseminate information on the volume of results which have been reported on fleet testing of vehicles using methanol/gasoline blends, in order to compare the different test conditions, reporting procedures, etc. and determine if some common elements pervade which provide a degree of consistency in understanding the significance of the results. In addition, it should be possible to compare the results of the relatively uncontrolled fleet testing, with the controlled conditions of the present test program using an all weather chassis dynamometer, and perhaps lead to determining the direction of future blend fuel test programs.

The data services used for this review included library literature searches, references from past COFA and OFA meetings, past ORF programs and SAE publications. In order to restrict the

data assessment to programs which are not greatly out of date with respect to current practice, only vehicle test programs which were started later than 1980 were considered. The review was also restricted to driveability issues, and other efforts, such as impact on materials, was not included, except in as far as that it directly affected driveability.

For each reference studied, special attention was given to a number of critical parameters which could impact on driveability results. These are:

- **Fuel Type** — composition of the fuel blend, choice of cosolvent.
- **Fuel Volatility** — adjustment of volatility to maintain same RVP as base gasoline, or allowing RVP to float.
- **Vehicles** — number and type of vehicles and fuel systems.
- **Test Conditions** — environmental conditions under which the tests were conducted; test track or service use; period of the test.
- **Drivers** — use of trained drivers, fleet operators, or owner operated.
- **Rating Method** — Demerit point system, log book, or subjective induction.
- **Driver Awareness** — blend test, or drivers aware of when fuel blends were being used.
- **Results** — effects rated on driveability.
- **Comments** — other comments with respect to special information on the test program.

Table 8 summarizes the results of particularly relevant programs under these headings. In many cases, the fuel blends were adjusted to CGSB specifications for gasolines, or to equivalent RVP's as the base regular unleaded gasoline (RUG), but in some cases, a blend decrease of the T_{10} and T_{50} points was made, or the RVP was allowed to increase from that of the base RUG. There is a considerable mix of different vehicle types, and test procedures, and the effects of the blends on driveability are also reported to vary considerably.

In reference 1, no deterioration in driveability was reported by trained drivers using a test track. In the case of reference 2, the fleet vehicles were operated by different drivers, who did

not perceive any difference in driveability with the fuel blends, while in reference 3, differences in driveability noted by the fleet drivers using a blend adjusted to CGSB specifications, essentially disappeared when the T_{10} and T_{50} points of the blend were reduced from that of the RUG. In reference 4, however, owner operated vehicles were used, and the drivers reported more complaints in driveability using the blend adjusted to the same RVP as the base RUG. For references 5 to 7, taxi drivers had no complaints of driveability on the blend when adjusted to CGSB specifications, and trained drivers at Kaptest also showed no significant difference in driveability between the blends and RUG fuels. However, owner operated drivers detected differences in driveability even when the blends were used in blind testing, and had lower T_{50}'s and higher RVP's than the base RUG fuels. In reference 8, increased driver complaints were reported with the Oxinol fuel, and driveability problems were also reported in reference 9 where the blends had higher RVP's and lower T_{50}'s. In contrast, reports from fleet tests with the Tennessee Valley Authority found no statistical difference in driveability when operating with a blend which had similar volatility to that of the base gasoline. In reference 11, most drivers were satisfied with the blend, but it should be noted that only 3% methanol was used in the blend without co-solvent. Reference 12 reports work with fuel injected vehicles typical of new passenger cars using electronic fuel injection equipment. Various volatilities of methanol blends were used, and in all cases, the blend resulted in a deterioration of hot driveability with respect to hot start cranking time.

A number of observations can be made at this stage. It appears that if owner operated vehicles are used in test programs, greater sensitivity in results are obtained. Drivers of fleet vehicles appear more tolerant of driveability issues, probably because of less familiarity with driving the vehicle. Lowering the T_{50} point compared with the base gasoline improved driveability in some cases, but in other cases, driveability effects were still noted with the blend. In the latter case, however, only one type of vehicle was used in the test program (7 on this blend, and 7 on RUG), so the effects noted may have been due to vehicle sensitivity. In one other case, a significant effect of blends of various volatilities was noted on hot driveability.

A number of reports on driveability issues with methanol blends were also received from COFA which had been submitted to them by Chrysler Corporation. These were also reviewed within the current perspective. While all of the reports showed deterioration in driveability with use of methanol blends, the degree of the effect was not always clear. Perspective appears to be an important parameter within which results are summarized, and it appears that the conclusions reached on any one study are largely a result of a particular author's perspective. For example, in summarizing the same report, one author comments

that "vehicles may experience a significant deterioration in driveability due to the leaning effect" of the blend, while another author summarizes the same report as follows, "Although the average car can tolerate the small leaning effect with very little impact, cars that are already lean for emission compliance, or due to production variability, may experience a significant deterioration in driveability."

Perhaps the best example of different perspectives is demonstrated with respect to the ARCO/TVA study involving Tennessee Valley Authority fleet cars which is summarized in Tables 9 and 10. Table 10 shows the actual driveability results reported, while Table 9 shows the different perspectives placed on the conclusions reached by different companies reporting on the tests. TVA appeared the most tolerant, reporting that the blend performance was not statistically different from the base gasoline during all seasons. For the same results, ARCO reported some Spring driveability problems with some of the cars, while Chrysler reported a 500% increase in the number of days dissatisfied per 100 days driven. All statements with respect to the same set of results are correct, but the perspective differs in considering the degree of the impact on driveability.

A further example of this view is shown in Tables 11 and 12. Table 11 summarizes a Texaco study involving 200 employee-owned cars and methanol blends involving 6% methanol and various co-solvents. Texaco reports a definite difference in performance, and warmed-up driveability degradation with use of the blends. The actual results (Table 12) show demerits per trip increase from 0.9 on gasoline to 1.5 on blend B and 1.7 on blend A, while the percent satisfaction for all cars was 95.2% on Blend B, 94.6% on Blend A and 97.3% on the base gasoline. Again, there is a judgement call on how serious the impact of blends will be on driveability, if their use was widespread.

7. CONCLUSIONS

The results of the present study carried out under controlled conditions on an all weather chassis dynamometer are consistent with the results of other fleet trials. Some vehicles show more sensitivity to the blends than others, and one vehicle type appeared to favour a higher RVP for the fuel blend at -20°C. However, there was also a tendency for increased hot driveability problems with the higher RVP fuels for two of the vehicles, suggesting that some balance would have to be achieved between cold and hot driveability issues. Testing over a wider range of vehicles will be required to determine the balance point where greatest benefits may be achieved with use of higher RVP fuel blends without serious impact on hot driveability.

Review of past fleet tests with methanol blends has shown a considerable spread in the conclusions drawn, from those satisfied with blend performance, to those who feel that use of methanol blends is totally unacceptable. There seems to be little doubt that some cars are more sensitive to use of the blends than others, and therefore, some degree of driveability problems will be experienced with some cars. It is not clear, however, how perceptible these driveability effects will be if blends were used on a wide scale, since many drivers currently experience similar phenomena with gasoline, depending on the model, age, and state of maintenance of the car by the driver. Perhaps the most reasonable conclusion which can be reached at present is reflected in the following summary of the situation reported by the US EPA.

As a general objective, the driveability of many vehicles on low level alcohol blends appears to be roughly equivalent to that of gasoline. However, there are indications of problems with some vehicles and certain operating conditions. These problems seem to occur less on vehicles with fuel injection and closed-loop systems which are more prevalent in recent model years. These problems seem to occur somewhat more on vehicles with carburetors especially those without feed-back to control air:fuel ratio. While driveability problems of the type discussed above are noted more with blends than with gasoline, it is not clear that the problems would be perceptible to some degree. Nevertheless, the possibility of some increased driveability complaints due to increased use of gasoline/alcohol blends cannot be ruled out, although such complaints may not be numerous.

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TABLE 1

TEST FUELS

Fuel	Oxygenates	RVP, kPa	T10, °C	T50, °C	T90, °C	RON	MON
A	-	101	31	75	156	97.4	86.9
B	5% MeOH-3% EtOH	101	37	75	154	100.3	88.8
C	5% MeOH-3% EtOH	114	33	73	157	100.3	88.7
D	5% MeOH-3% EtOH	127	29	74	158	100.7	88.9
E	4 1/2% MeOH-4 1/2% IPA	123	29	70	155	100.2	88.7

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TABLE 2

LOW TEMPERATURE VOLATILITY OF THE TEST FUELS

Fuel	RVP, kPa(1)	"RVP", kPa		
		23.9°C	1.7°C	-12°C
A	101	69	28	17
B	101	60	23	14
C	114	70	29	12
D	127	81	33	20
E	123	80	32	21

(1) 37.8°C

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TABLE 3

TEST VEHICLES

A. 1984 Chevrolet Celebrity.

Engine	:	2.8l V6
Carb	:	2bbl 2-stage
Trans	:	3-speed auto with lock-up
Mileage	:	67798 km
Emission Controls	:	Catalytic convertor
		EGR
		Heated air intake
		Spark delay
		Charcoal cannister
		Electric grid carb preheat

B. 1983 Ford Escort.

Engine	:	1.6l OHV 4
Carb	:	2bbl 2-stage
Trans	:	3-speed auto
Mileage	:	82019 km
Emission Controls	:	Catalytic convertor
		EGR
		Heated air intake
		Spark delay
		Charcoal cannister
		Coolant carb preheat

C. 1982 Dodge Omni.

Engine	:	2.2l OHV 4
Carb	:	2bbl 2-stage
Trans	:	3-speed auto
Mileage	:	107314 km
Emission Controls	:	Air injection reactor
		EGR
		Heated air intake
		Spark delay
		Charcoal cannister
		Coolant carb preheat

TABLE 4

COLD-START AND DRIVEABILITY TEST RESULTS AT -20°C

		Fuel A		Fuel B		Fuel C		Fuel D		Fuel E	
		Run 1(1)	Run 2(2)	Run 1(1)	Run 2(2)	Run 1(1)	Run 2(2)	Run 1(1)	Run 2(2)	Run 1(1)	Run 2(2)
Vehicle A, (Celebrity)	Demerits	8	6	8	6	9	13	9	10	6	9
	Restart(3)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Vehicle B, (Escort)	Demerits	15	17	38	38	31	24	29	25	10	15
	Restart(3)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Vehicle C, (Omni)	Demerits	24	25	21	41	25	34	26	25	25	22
	Restart(3)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

(1) Overnight soak.
(2) 6 hour forced air soak.
(3) After reaching maximum temperature after shutdown.

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TABLE 5

COLD-START AND DRIVEABILITY TEST RESULTS AT -20°C PRE-TEST TEMPERATURES

	Fuel A		Fuel B		Fuel C		Fuel D		Fuel E	
	Run 1(1)	Run 2(2)	Run 1(1)	Run 2(2)	Run 1(1)	Run 2(2)	Run 1(1)	Run 2(2)	Run 1(1)	Run 2(2)
Vehicle A, °C										
Oil Sump	-19.1	-17.5	-18.7	-16.6	-18.4	-16.7	-19.2	-16.9	-18.8	-17.3
Coolant	-19.0	-18.6	-19.2	-18.7	-19.0	-19.5	-19.2	-19.4	-19.0	-18.8
Carburettor	-19.3	-19.0	-19.3	-18.4	-19.1	-19.8	-19.6	-19.9	-19.3	-19.3
Vehicle B, °C										
Oil Sump	-19.5	-17.7	-19.6	-18.0	-19.4	-18.0	-19.5	-18.1	-19.5	-17.9
Coolant	-19.4	-19.3	-19.6	-19.2	-19.4	-19.3	-19.5	-19.7	-19.4	-19.1
Carburettor	-19.8	-19.3	-19.8	-19.1	-19.6	-19.4	-19.6	-19.6	-19.7	-19.3
Vehicle C, °C										
Oil Sump	-19.2	-17.9	-19.2	-17.4	-19.3	-18.2	-19.3	-18.1	-19.3	-17.8
Coolant	-19.1	-18.9	-19.6	-19.1	-19.4	-19.4	-19.4	-19.3	-19.3	-19.0
Carburettor	-19.6	-19.6	-19.8	-19.6	-19.6	-19.7	-19.8	-19.7	-19.6	-19.8

(1) Overnight soak.
(2) 6 hour forced air soak.

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TABLE 6

HOT DRIVEABILITY TEST RESULTS AT 15°C

Vehicle A (Celebrity)

		Start Time (sec)	Idle Quality	Acceleration Time 0-50 km/hr (sec)	Acceleration Time 50-110 km/hr (sec)	Comments
Fuel A	- No Detent	4	Good	9.5	55	Stumble
	No Detent			6.0	65	Stumble
	Detent			6.0	11.5	Sluggish
Fuel B	- No Detent	3	Good	7.0	57	Stumble
	No Detent			6.5	51	Stumble
	Detent			7.0	11.5	O.K.
Fuel C	- No Detent	3	Good	5.5	53	Very Rough Stumble
	No Detent			5.2	53	Very Rough Stumble
	Detent			5.3	12	O.K.
Fuel D	- No Detent	4	Good	6.0	57	Stumble
	No Detent			5.3	82	Rough Stumble
	Detent			5.5	13.3	O.K.
Fuel E	- No Detent	3	Light Rough	7.0	83	Rough Stumble
	No Detent			5.1	85	Very Rough Stumble
	Detent			5.5	12	O.K.

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TABLE 6 (CONT'D)

HOT DRIVEABILITY TEST RESULTS AT 15°C

Vehicle B (Escort)

		Start Time (sec)	Idle Quality	Acceleration Time 0-50 km/hr (sec)	Acceleration Time 50-110 km/hr (sec)	Comments
Fuel A	- No Detent	4	Good	13	30	O.K.
	No Detent			11	27	O.K.
	Detent			-	-	-
Fuel B	- No Detent	2	Good	10	24	O.K.
	No Detent			10	29	O.K.
	Detent			9	17.5	O.K.
Fuel C	- No Detent	2	Light Rough	9	31	O.K.
	No Detent	(Stall)		9.3	26	O.K.
	Detent	Restarted		9	17.5	O.K.
Fuel D	- No Detent	2	Light Rough	8.5	43	Stumble
	No Detent			10	26	O.K.
	Detent			10	16	O.K.
Fuel E	- No Detent	2	Good	8	34	Stumble
	No Detent			9	23	O.K.
	Detent			8.5	17	O.K.

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TABLE 7

HOT DRIVEABILITY TEST AT 15°C SOAK TEMPERATURES(1)

		Vehicle A (Celebrity)		Vehicle B (Escort)	
		Before	After	Before	After
Fuel A, °C					
	Oil Sump	103	87	108	102
	Carburetor	37	54	17	49
	Block	83	92	67	77
Fuel B, °C					
	Oil Sump	107	92	112	103
	Carburetor	39	53	21	50
	Block	83	92	71	69
Fuel C, °C					
	Oil Sump	107	89	113	105
	Carburetor	38	56	22	49
	Block	82	92	65	71
Fuel D, °C					
	Oil Sump	107	92	115	105
	Carburetor	36	54	23	50
	Block	82	93	66	70
Fuel E, °C					
	Oil Sump	107	91	115	106
	Carburetor	28	55	24	49
	Block	80	93	65	70

(1) 15 minutes with tarpaulin on hood.

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SURVEY OF FLEET TESTING

TABLE 8

REFERENCE	FUEL TYPE	FUEL VOLATILITY	VEHICLES	TEST PERIOD AND CONDITIONS	DRIVERS	RATING METHOD	DRIVER AWARENESS	RESULTS	COMMENTS
(1) SAE 841382 The effects of oxygenates on int. temperature driveability of 1983/1984 cars T.V.A.	Base - RUG 10% oxinol 10% oxinol 10% oxinol	- Added to base - RVP same as base butane out - Reformate added to match base dist.	16 rentals imports + domestics 1983-84 Various fuel syst.	Oct. 83 Jan. 84 3-1/2 mile Test track 38 to 65oF No rain	2 trained	Demerits	Blind Test	Blending of oxygenates up to 3.7% does not deteriorate drive-characteristics of a volatility class of fuels.	CRC cold start warm up drive-ability
(2) MTC - MOE Methanol/hydro-carbon fuel. Blend fleet demonstration project.	7% MeOH 3% IPA	Adjusted to CGSB specifications.	9 company 1977-82 domestics	June 1982 June 1984 Chassis dyno and fleet use	Fleet Operators and trained	Demerits and subjective	Yes	Blend fuel tested acceptable under fleet operating conditions. Some vehicles had more noticeable drive-ability faults with blend during cold engine operation.	Considerable cross fueling. Fleet A-75% Blend Fleet B-32% Blend
			30 company 1979-82 domestics	Typical fleet use	Fleet operators	Subjective	Yes		
(3) Manitoba fleet test	Base - RUG 4.75% MeOH 4.75% IBA	Adjusted to CGSB draft for oxygenates	45 blend 32 RUG 1979-85 mostly domestics	August 1984 March 1986 Normal use	Fleet operators	Subjective weekly survey	?	Differences in drive-ability reduced to statistically insignificant over course of demo due to blend decrease of T10 and T50 compared to RUG.	
				27.5 Km test route 21 tests	Trained	Demerits			
(4) Imperial Oil Brief to Standing Committee on Natural Resources and Public Works. Appendix II December 1985.	Base - RUG 4.75 MeOH 4.75 TBA	Same RVP Winter + Summer	30 RUG 30 blend 1977-84	Summer 1984 Normal use	Owner operated	Log book	Blind	Overall more driver complaints with blend compared to RUG.	Harder starting rough idling and sluggishness.
	Base-RUG 4.75 MeOH 4.75 TBA	RVP adjusted	25 RUG 25 blend 1980-85	Winter & Spring 1985	Owner operated	Log book	Blind		

SURVEY OF FLEET TESTING

REFERENCE	FUEL TYPE	FUEL VOLATILITY	TEST PERIOD VEHICLES	TEST PERIOD AND CONDITIONS	DRIVERS	RATING METHOD	DRIVER AWARENESS	RESULTS	COMMENTS
(5) Evaluation of MeOH/IBA gasoline blend under Canadian driving conditions. Celanese/ORF Report April 1984	4.75% MeOH 4.75% IBA	Blended to CGSB specifications.	12 blend 10 control 1982 Chev V-8's	Summer 1982 to Summer 1983 Normal use	Taxi drivers	Log books subjective	?	No driving conditions in which blend performed any differently than RUG.	
			12 late model domestics		Company car drivers	Log bookr subjective	Blind		
(6) Evaluation of vehicle cold starting and driveability performance. Celanese-Kaptest 1982	RUG 4.75% MeOH 4.75% IBA		2-1981 GM V-8's	-10oC -36oC	Kaptest trained	Demerits	Yes	No significant difference between fuels.	
(7) Fleet test program 6:2 methanol:cosol. gasoline blend. Celanese-ORF 1986.	RUG 6% MeOH 2% IBA ARCO 4-3/4 - 4-3/4	Seasonally adjusted.	62 owner or company cars 1975-84	June 1984 Mar. 1985 Normal use.	Owner operated	Log book	Blind	Winter, summer and ARCO blends poorer driveability compared to RUG. Winter blend better than summer.	All blends had lower T50 than RUG and higher RVP.
			5 fleet cars 1977-84 domestics.	Test route	ORF-MTC trained	Demerits	Yes	Slightly more demerits with blends than RUG. Not as severe as fleet results.	2 cars tested by MTC with MTC 10% blend vs 6 & 2 and RUG.
(8) Project for reliability fleet testing of alcohol/gasoline blends. DOE-SWRI Contra Costa County App. H. Dec. 1985	RUG - Oxinol	-9.7 RVP -12.1 RVP	15 blend 15 RUG 1975-78 domestics county vehicles	13 months testing general service	Random drivers	Driver reports	Blind	Significantly higher percentage of cranking, hesitation and power problems with Oxinol than RUG. No reports of engine or fuel system failures therefore up to 10% alcohol could be used for fleet	RUG fuel specs. Oxinol Base T10 108 123 T50 191 210 T90 334 332

SURVEY OF FLEET TESTING

REFERENCE	FUEL TYPE	FUEL VOLATILITY	VEHICLES	TEST PERIOD AND CONDITIONS	DRIVERS	RATING METHOD	DRIVER AWARENESS	RESULTS	COMMENTS
(9) Project for reliability fleet testing of alcohol/gasoline blends. DOE-SWRI SWRI fleet App. I. Dec. 1985	RUG 4% MeOH 2.1% EOH 2.1% TBA	Summer & Winter grade comparisons	7 RUG 7 blend all company 1984 Escorts	Dec. 83 Dec. 84 Normal use	Company drivers	Driver reports	?	All categories except cranking, ping, dieseling blend had poorer performance than RUG. RUG had more pinging problems than blend.	Blends had higher RVP and lower T50.
(10) Effect of methanol gasoline blends on vehicle fuel economy, driveability and fuel system durability 1984 Fuels & Lubricants Mtg.	RUG 4-1/2% MeOH 4-1/2% TBA	Similar volatility	140 TVA Fleet cars	Mar. 83 Apr. 84 Normal use.	TVA employees	Driver reports	?	For all seasons, blend performance was not statistically different than base fuel.	Results broken down into 4 seasons.
(11) SAE 870367 Fleet testing MeOH blends in public stations Israel Feb. 1987	3% MeOH No co-solvent	Max 8.5 8.5 lb RVP year round	14,000 public vehicles 1972-86 mostly European	Normal use	Owner operated	At each fill comments to attendant	Yes	Vast majority accepted only 2% dissatisfied. No phase separation.	At each fill on the spot engine adjustments if necessary.

SURVEY OF FLEET TESTING

REFERENCE	FUEL TYPE	FUEL VOLATILITY	VEHICLES	TEST PERIOD AND CONDITIONS	DRIVERS	RATING METHOD	DRIVER AWARENESS	RESULTS	COMMENTS
(12) SAE 870368 Effects of MeOH gasoline blends on hot weather driveability Toyota Feb. 1987	5 RUG and 6 MeOH blends	Various volatilities	2 Toyota 1 multi-point EFI 1 - Carb	Chassis dyno Ambient 40oC	Toyota	Hot start cranking time		Startability after engine off soak drastically deteriorates in EFI vehicles.	Main cause is vapour lock in injection nozzle.

SURVEY OF FLEET TESTING

TABLE 9

REFERENCE	FUEL TYPE	FUEL VOLATILITY	VEHICLES	TEST PERIOD AND CONDITIONS	DRIVERS	RATING METHOD	DRIVER AWARENESS	RESULTS	COMMENTS
Effect of methanol gasoline blends on vehicle fuel economy, driveability and fuel system durability 1984 Fuels & Lubricants Mtg. Att.#8	RUG 4-1/2% MeOH 4-1/2% TBA	Similar volatility	140 TVA Fleet cars	Mar. 83 Apr. 84 Normal use.	TVA employees	Driver reports	?	For all seasons, blend performance was not statistically different than base fuel. With the exception of of the spring test, no significant differences were detected between the test and base phase for any of the fuels tested. Concluded that factors other than oxygenate content caused the observed differences. Chrysler concerns - as much as 500% increase in no. of days dissatisfied per 100 days driven - as much as 150% increase in no. of cold engine problems per 100 cold starts, plus over 50 times more hot engine problems per 100 half hour driving periods.	Results broken down into 4 seasons.

TABLE 10

MUSCLE SHOALS FLEET TEST - 4.7 VX METHANOL/4.7 VX GTBA

	SPRING		SUMMER		FALL		WINTER	
	BASE	TEST	BASE	TEST	BASE	TEST	BASE	TEST
# DAYS DISSATISFIED / 100 DAYS DRIVEN	0.6	3.6	0.0	0.2	0.4	1.4	1.4	0.2
# COLD ENGINE PROBLEMS / 100 COLD STARTS	3.4	8.9	0.9	2.2	5.2	8.3	4.4	1.3
# HOT ENGINE PROBLEMS / 100 1/2 HR DRIV PERIODS	0.1	5.2	0.0	0.2	0.6	1.0	1.2	0.8
No Vehicles in fleet	28		21		25		24	

SURVEY OF FLEET TESTING

TABLE 11

REFERENCE	FUEL TYPE	FUEL VOLATILITY	VEHICLES	TEST PERIOD AND CONDITIONS	DRIVERS	RATING METHOD	DRIVER AWARENESS	RESULTS	COMMENTS
Consumer reaction program 200 employee owned cars Texaco Inc. Att.#9	RUG (G) 6% MeOH 2% TBA 6% MeOH 2% TBA	Max RVP for month (B) Same RVP as (G) DI adjusted (A) RVP +1.0-1.5 DI adjusted.	200 employee 1976-83 domestics	Sept. 1983 Sept. 1984 Normal use	Owner operated	Daily sheets	Blind	Warming up driveability similar for all fuels. There is definite difference in warmed up driveability performance between gasoline and either alcohol blend.	

TABLE 12

AVERAGE RESULTS - ONE YEAR

(70,000 QUESTIONNAIRES - 180,000 TRIPS)

FUEL		G	B	A	GB	GA
RVP		13.0	13.4	14.3	14.1	14.6
DI		218	202	204	210	210
WARMING-UP DRIVEABILITY						
TWD/TRIP	- ALL CARS	2.4	2.5	2.6	2.2	2.1
	- CHRYSLER	2.2	3.0	3.5		
SATISFACTION %	- ALL CARS	91.9	91.9	91.3	92.6	93.4
	- CHRYSLER	92.2	91.4	90.3		
WARMED-UP DRIVEABILITY						
TWD/TRIP	- ALL CARS	0.9	1.5	1.7	1.3	1.1
	- CHRYSLER	0.6	1.6	1.6		
SATISFACTION %	- ALL CARS	97.3	95.2	94.6	96.4	97.5
	- CHRYSLER	98.6	96.5	96.1		
KNOCK						
(R+M)/2		87.6	87.9	87.7	87.7	87.7
% SATISFACTION	- ALL CARS	95.8	96.9	97.1	95.9	96.3
	- CHRYSLER	97.9	98.7	98.7		

FIGURE 1

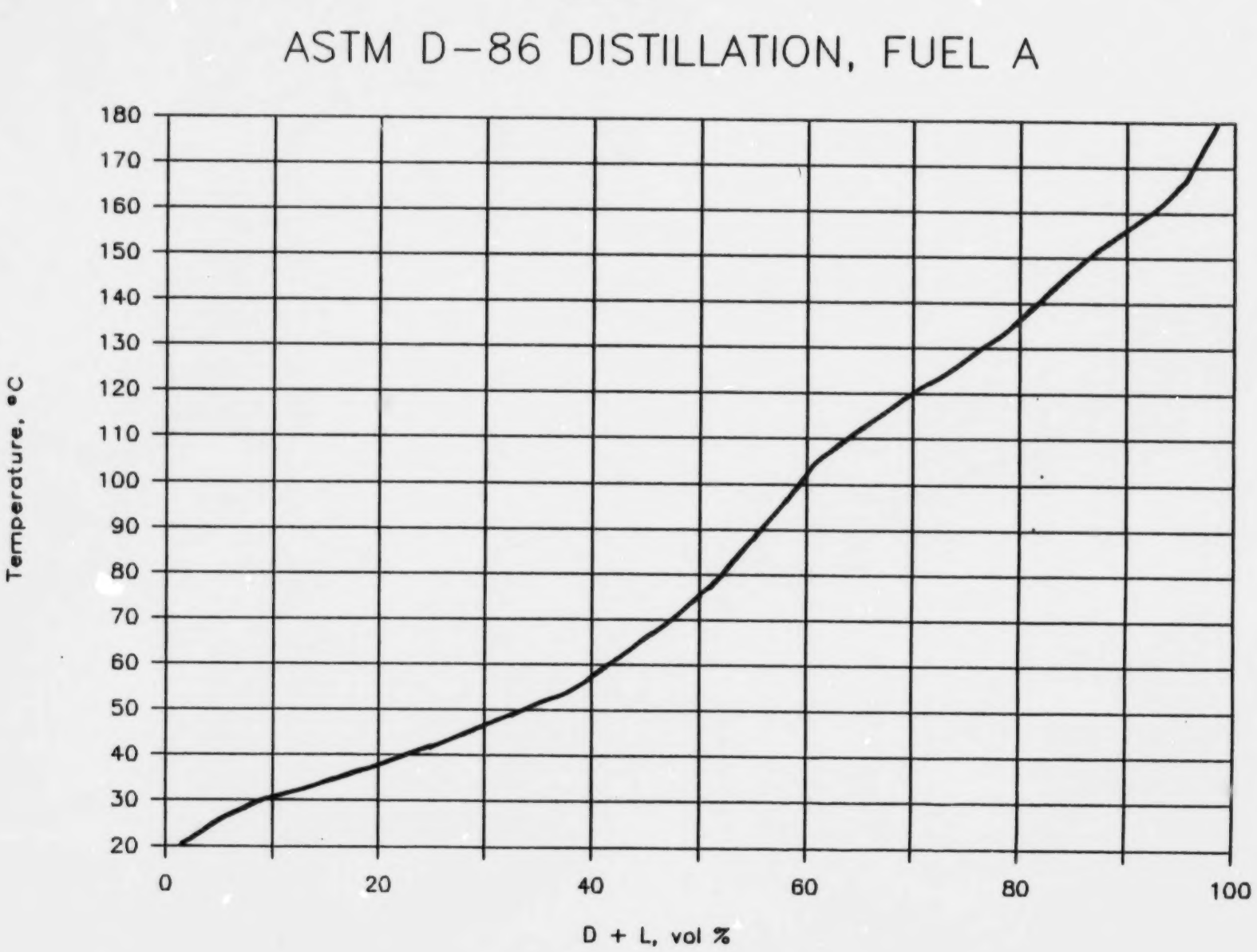

ASTM D-86 DISTILLATION, FUEL A
Temperature, °C
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
0
20
40
60
80
100
D + L, vol %

FIGURE 2

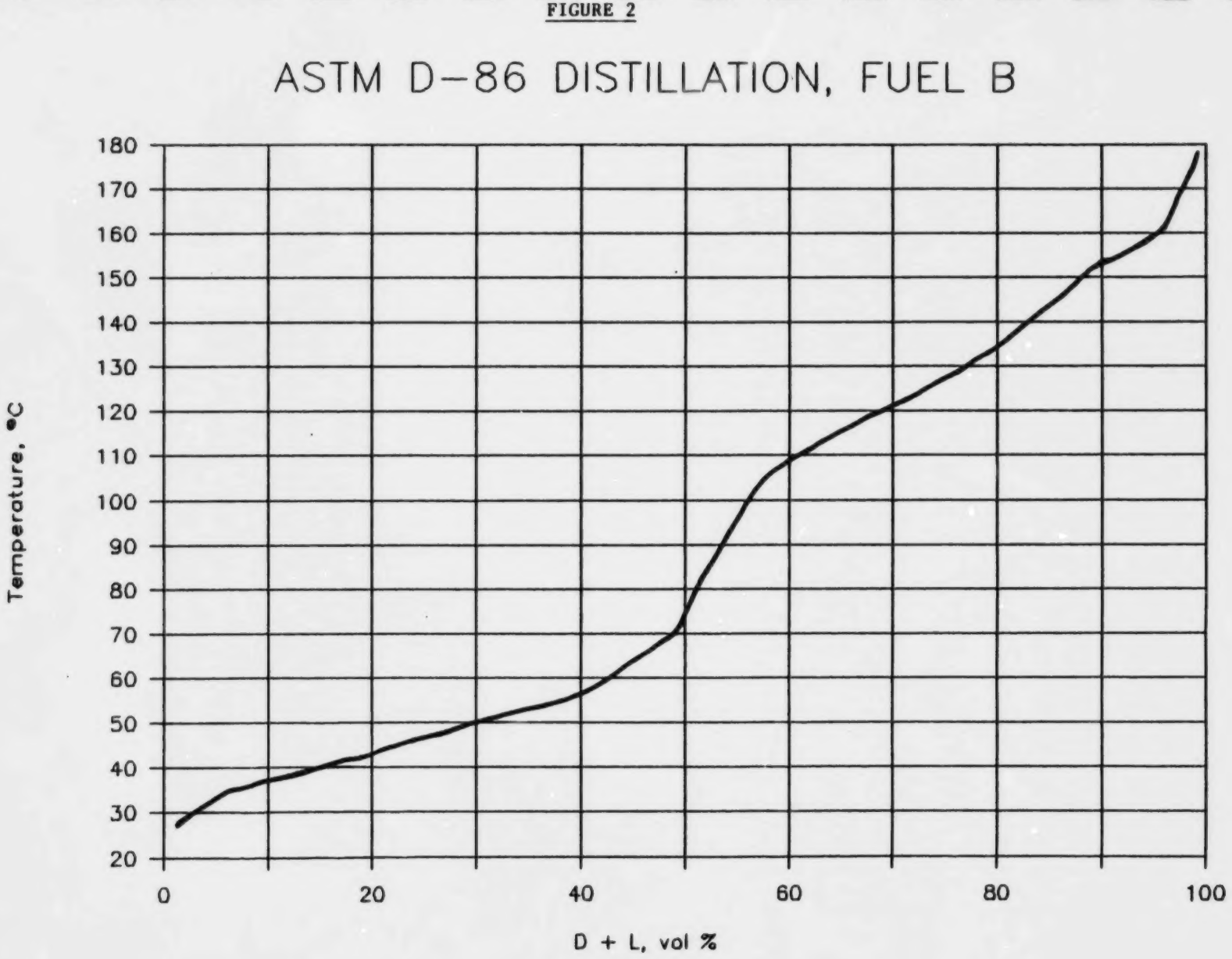

ASTM D-86 DISTILLATION, FUEL B
Temperature, °C
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
0
20
40
60
80
100
D + L, vol %

FIGURE 3

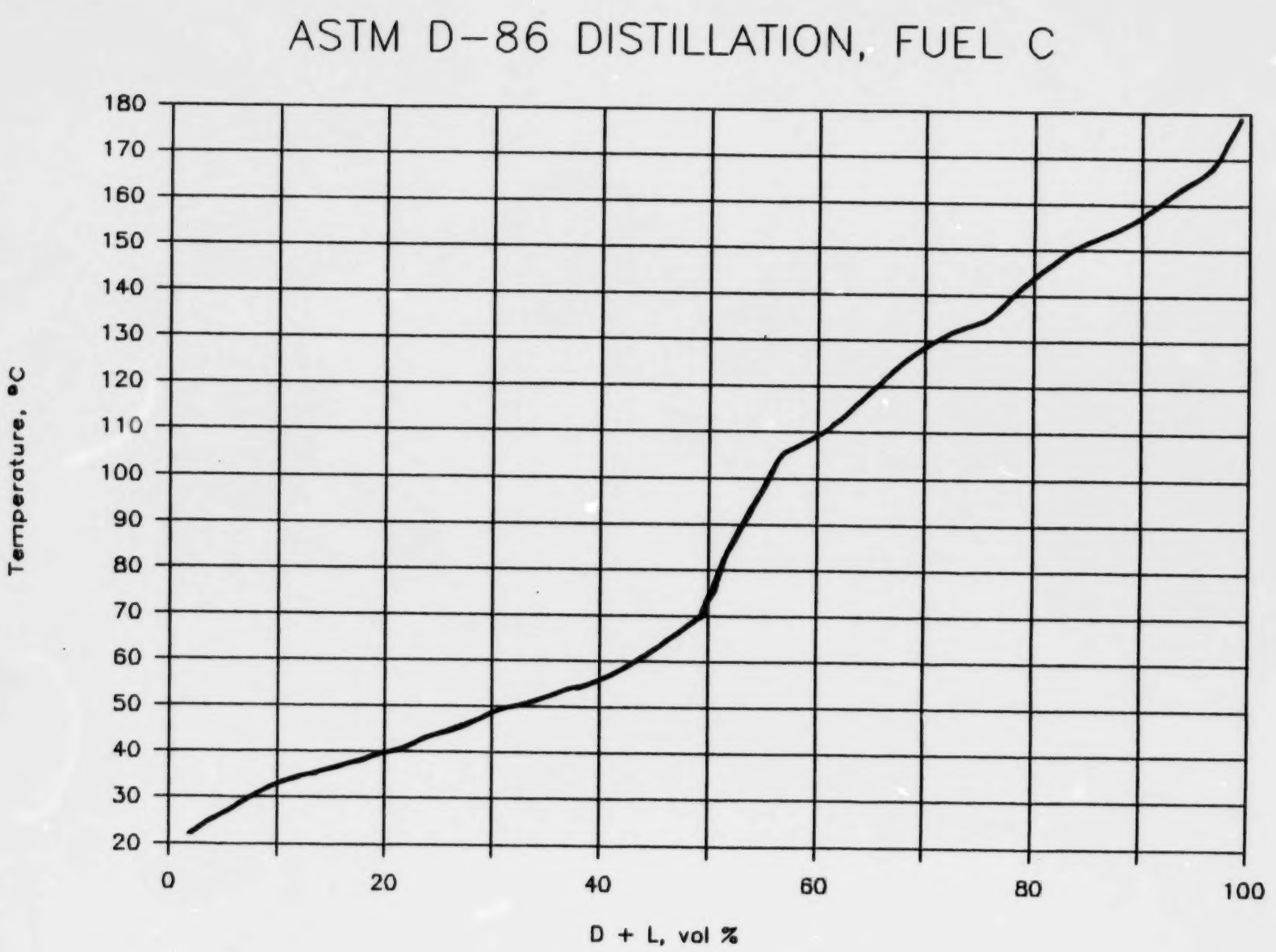

ASTM D-86 DISTILLATION, FUEL C
Temperature, °C
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
0
20
40
60
80
100
D + L, vol %

FIGURE 4

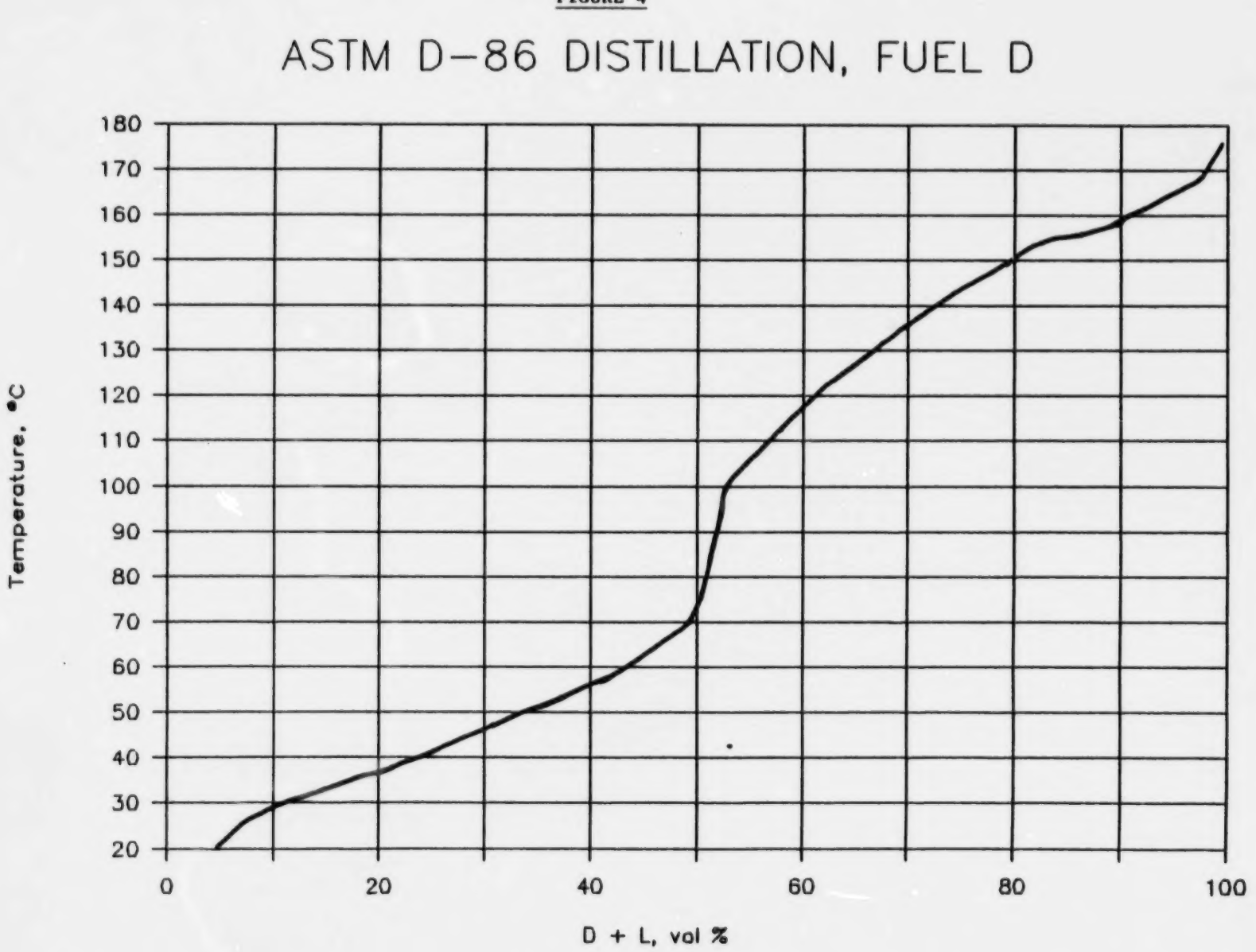

ASTM D-86 DISTILLATION, FUEL D
Temperature, °C
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
0
20
40
60
80
100
D + L, vol %

FIGURE 5

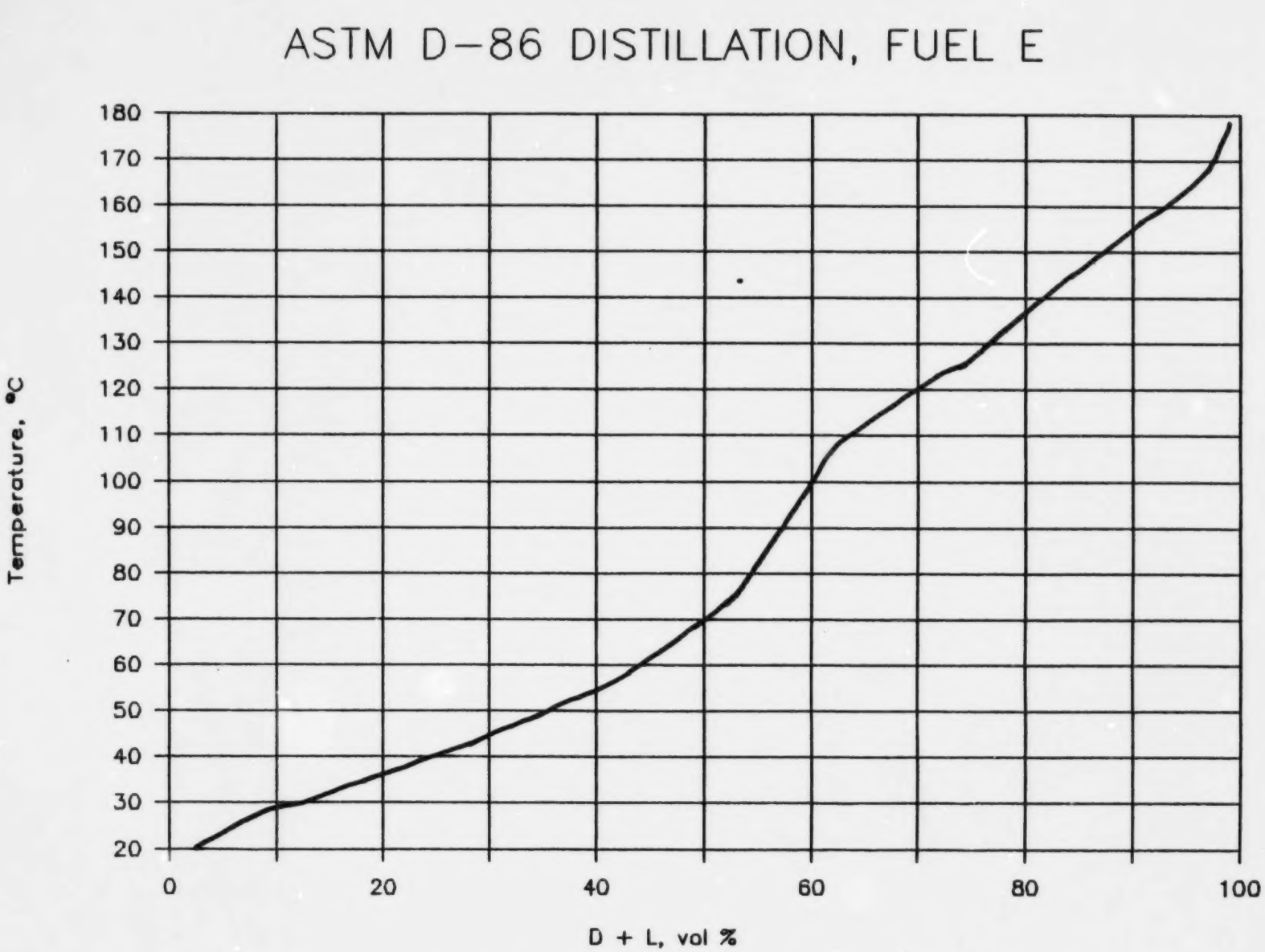
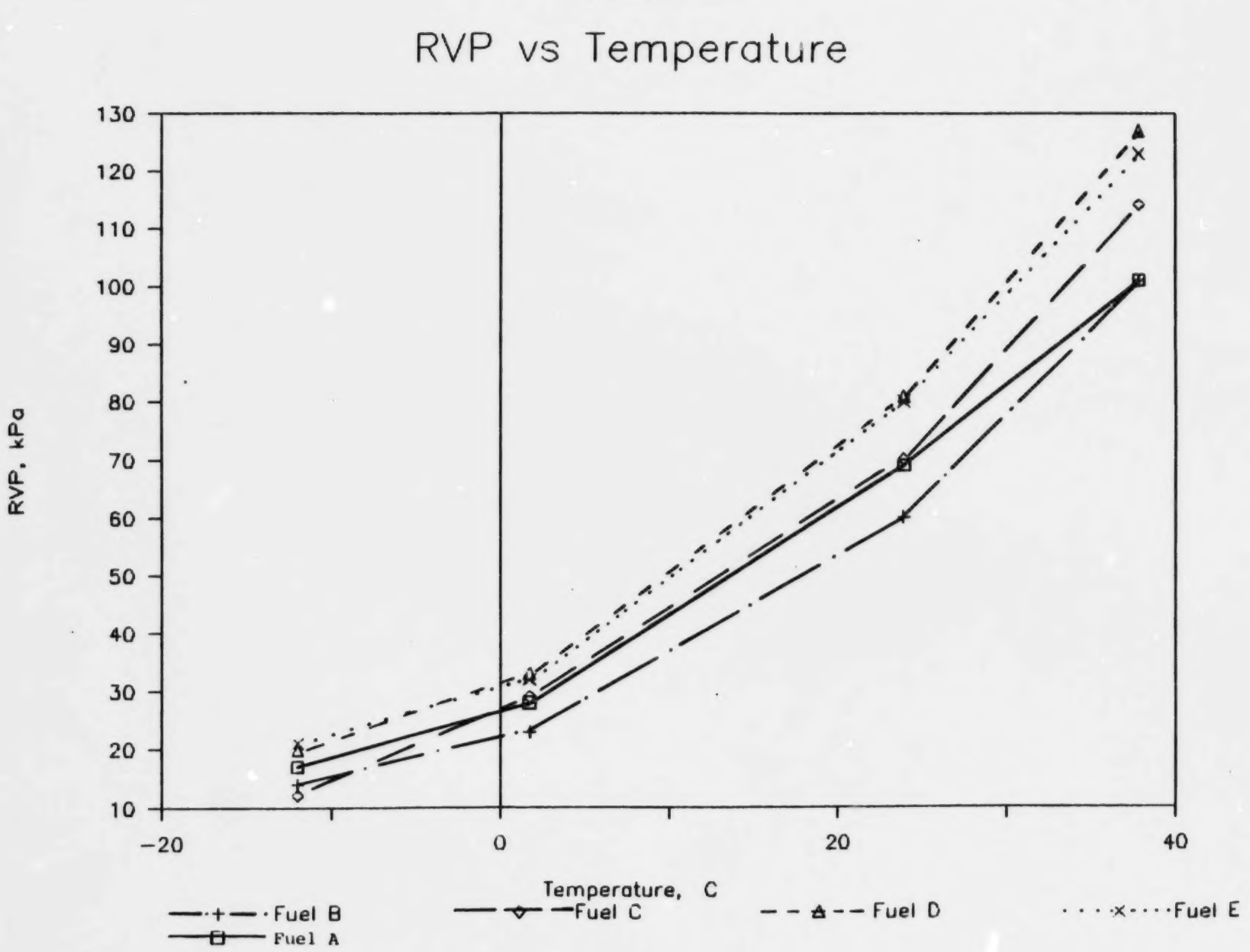

ASTM D-86 DISTILLATION, FUEL E
Temperature, °C
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
0
20
40
60
80
100
D + L, vol %

FIGURE 6


RVP vs Temperature
RVP, kPa
130
120
110
100
90
80
70
60
50
40
30
20
10
-20
0
20
40
Temperature, C
Fuel B
Fuel C
Fuel D
Fuel E
Fuel A

APPENDIX I

Cold Start and Driveability Test

APPENDIX I

COLD-START AND DRIVEABILITY TEST

1. Startup

    1. Start engine according to owner's manual and record start time. (Accessories on).

    2. Record engine speed, intake vacuum and idle quality in Neutral or Park immediately after start, with foot removed from throttle. (Fast idle cam).

    3. If engine stalls, repeat Step 1. Record the restart time, but do not record any stall for Step 1.

    4. After 5 seconds from start, accelerate engine briefly, and again release throttle; record engine speed, intake vacuum, idle quality. If engine stalls, record the stall and repeat Steps 1 through 4.

    5. After 20 seconds from start, apply brakes, shift to Reverse range and record engine speed, intake vacuum, idle quality and stalls.

    6. Shift from Reverse to Drive range after 35 seconds from start and record idle quality. If engine stalls, restart immediately. Do not record restart time. Record number of stalls.

2. Drive Cycle

Allow 5 seconds in drive range and start acceleration as below. (Rear defroster and lights on). Record all malfunctions. (See Sections 3 and 4).

Steps		Accumulated Distance, km
(1)	1/4 throttle to 30 km/h	
(2)	hold at 30 km and for 0.2 km total (include acceleration)	0.2
(3)	brake	
(4)	idle for 20 seconds in D.	
(5)	1/2 throttle to 40 km/h	
(6)	hold for 0.3 km total	0.5
(7)	brake	
(8)	idle 20 seconds in D.	
(9)	wide open throttle to 55 km/h (not detent, i.e. not passing gear)	
(10)	hold for 0.3 km total	0.8

APPENDIX I (CONT'D)

COLD-START AND DRIVEABILITY TEST

Steps		Accumulated Distance, km
(11)	brake	
(12)	idle 20 seconds in D.	
(13)	1/4 throttle to 40 km/h	
(14)	hold for 0.2 km total	1.0
(15)	3/4 throttle to 55 km/h	
(16)	hold for 0.3 km total	1.3
(17)	brake	
(18)	idle 20 seconds in D.	
(19)	interrupted acceleration - 1/2 throttle followed by quick stop (0.5-1.5 m)	
(20)	1/2 throttle to 55 km/h	
(21)	hold for 0.3 km total	1.6
(22)	brake	
(23)	idle for 20 seconds in D.	
(24)	wide open throttle to 70 km/h	
(25)	hold for 0.6 km total	2.2
(26)	brake	
(27)	idle for 20 seconds in D.	
(28)	1/4 throttle to 40 km/h	
(29)	hold for 0.2 km total	2.4
(30)	3/4 throttle to 55 km/h	
(31)	hold for 0.3 km total	2.7
(32)	brake	
(33)	idle for 20 seconds in D.	
(34)	3/4 throttle to 65 km/h	
(35)	hold for 0.8 km total	3.5
(36)	brake	
(37)	idle for 20 seconds in D.	
(38)	3/4 throttle to 90 km/h	
(39)	hold for 0.5 km total	4.0
(40)	wide open throttle to 110 km/h	
(41)	hold for 0.5 km total	4.5
(42)	brake	
(43)	idle for 20 seconds in D.	
(44)	repeat steps (1-43)	

Footnote: 10 minutes approximately for each cycle. Total test time 20 minutes.

COLD-START AND DRIVEABILITY TEST

3. Malfunctions

1. Stall

Any occasion during a test when the engine stops after the engine has been started properly.

Three types of stall are:

(a) Stall; idle - Any stall experienced when the vehicle is not in motion, or when a maneuver is not being attempted.

(b) Stall; maneuvering - Any stall which occurs during a prescribed maneuver or attempted maneuver.

(c) Stall; decelerating - Any stall which occurs while decelerating between maneuvers.

2. Idle Roughness

An evaluation of the idle quality or degree of smoothness while the engine is idling.

3. Backfire

An explosion in the induction or exhaust system.

4. Hesitation

A temporary lack of vehicle reponse to opening of the throttle.

5. Stumble

A short sharp reduction in acceleration after the vehicle is in motion.

6. Surge

Power fluctuations occurring during acceleration or cruise.

APPENDIX I (CONT'D)

COLD-START AND DRIVEABILITY TEST

4. Malfunction Severity Ratings

1. Light (L) - A level of malfunction severity that is just noticeable to a trained driver.

2. Medium (M) - A level of malfunction severity that is noticeable to the average driver.

3. Heavy (H) - A level of malfunction that is pronounced and obvious to the driver.

APPENDIX II

Rating Procedure

APPENDIX II - RATING PROCEDURE

The demerits for any manoeuver are the sum of the demerits for the noted faults at the noted severities for the maneuver. All disturbances should be identified, but the maximum demerits per maneuver (excluding cranking time) is not to exceed 12, as scored.

Demerits assigned for engine start time will be assigned as follows:

1 demerits/second over initial 5 second grace period, with a one second grace period per restart after stall.

Demerits for engine stalls occurring during the cold start/cold idle evaluation, will be assigned as follows:

- 3 demerits/stall while in Neutral or Park
- 4 demerits/stall while in Drive or Reverse

Demerits for engine stalls occurring during the warm-up driving evaluation, will be assigned as follows:

- 6 demerits/stall while idling
- 6 demerits/stall during VEHICLE False Start MANOEUVER
- 12 demerits/stall while driving

Demerits for areas rated subjectively will be assigned as follows:

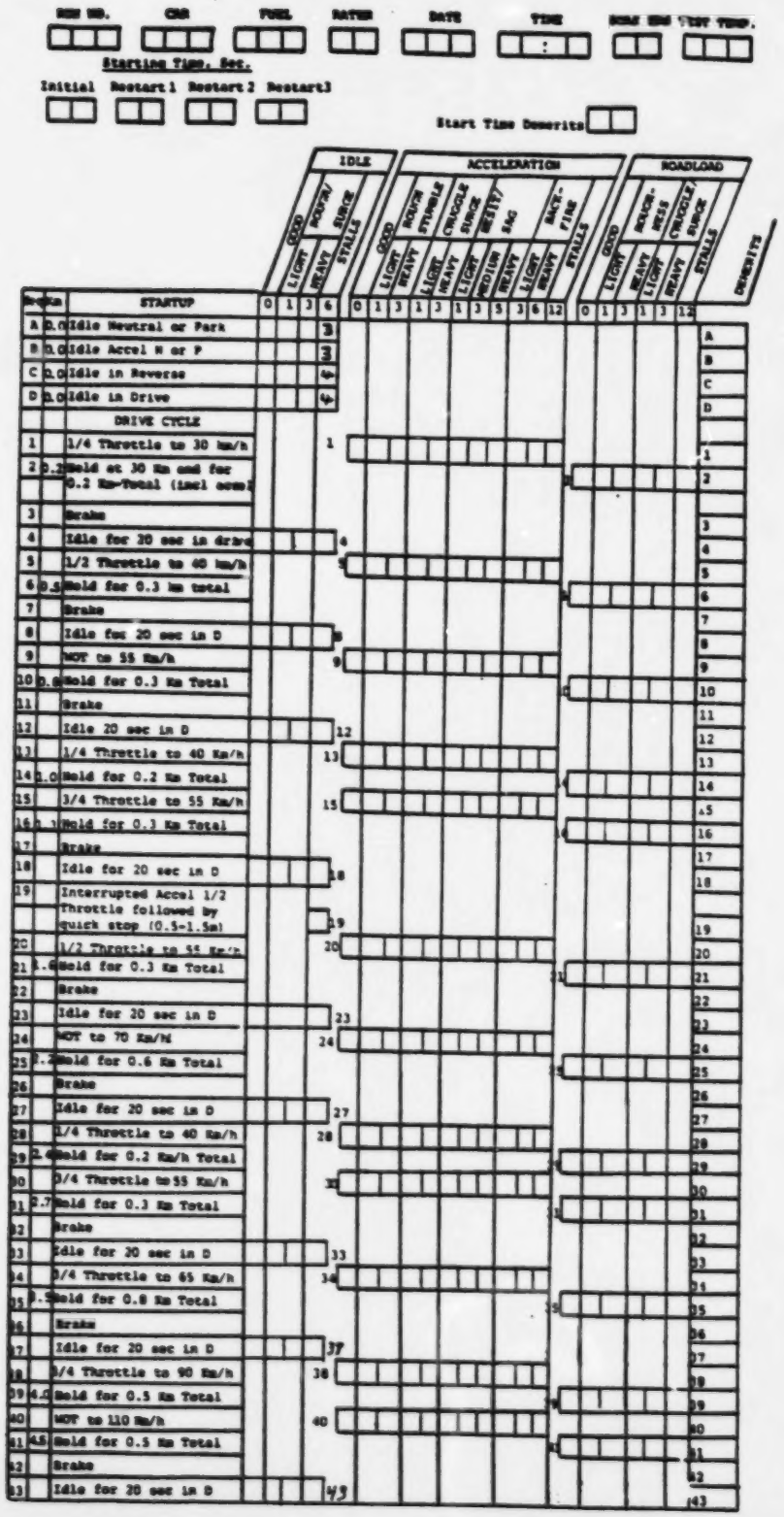
Subjective Areas	Demerits for Disturbance Levels			
	Good	Light	Medium	Heavy
o Roughness	0	1	-	3
o Surge/Chuggle	0	1	-	3
o Hesitation/Sag	0	1	3	5
o Backfire (Afterfire)	0	3	-	6
o Idle Evaluations	---- (Use Roughness Demerits) -----			

APPENDIX III

Rating Form

APPENDIX III

RATING FORM



APPENDIX IV

Hot Driveability Test

APPENDIX IV

HOT DRIVEABILITY TEST

1. Soak vehicle overnight in AWCD at 15°C.
2. Start vehicle and drive on dynomometer at 80 km/hr for 15 minutes.
3. Stop vehicle and cover hood with tarpaulin for 15 minutes.
4. Remove tarpaulin and restart vehicle, recording starting time.
5. Idle in N for 20 seconds, noting idle quality.
6. Accelerate at half-throttle to 50 km/hr, recording acceleration time.
7. Accelerate at full-throttle (no detent) from 50 to 110 km/hr, recording acceleration time.
8. Brake to stop.
9. Repeat Steps 6-8.
10. Repeat Step 6.
11. Accelerate at wide-open throttle (detent) from 50 to 110 km/hr, recording acceleration time.
12. Brake to stop.
13. Change fuel, drive at 80 km/hr for 5 minutes and repeat Steps 3-12.

APPENDIX V

Demerit Points

APPENDIX V

DEMERIT POINTS

Fuel		Fuel A						Fuel B						Fuel C					
Car		A		B		C		A		B		C		A		B		C	
Run		1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Start Demerit		1																2	
Idle																			
	Good																		
Rough/Surge	Light	1	1	3	2	1	2	3		1	1			1	1	1		2	2
	Heavy	3				6	6	3		9	3	9	6	3		3	6	6	3
Stalls									4		7		4		4	4			4
Idle																			
During Cycle					3	3		1	2	4	11	7	12	1	1	1		10	8
Acceleration																			
	Good																		
Rough/Stumble	Light	3	2			7	5			3			4	2	1	2	1	2	4
	Heavy					6	3					3					3	3	3
Chuggle/Surge	Light																		
	Heavy																		
Hesitation/Sag	Light		1			1	6	1		2	4	2	1		5	2	2		2
	Medium						3			6						3			
	Heavy												5						
Backfire	Light																		
	Heavy																		
Stalls				12	12					12	12					3			
Interruptions																12	12		
													6						6
Road Load																			
	Good																		
Roughness	Light		2										3	2	1				2
	Heavy																		
Chuggle/Surge	Light									1									
	Heavy																		
Stalls																			
Total		8	6	15	17	24	25	8	6	38	38	21	41	9	13	31	24	25	34

I.D. Campbell/mrp
87 07 02
1304s

APPENDIX V (CONT'D)

DEMERIT POINTS

Fuel		Fuel D						Fuel E					
Car		A		B		C		A		B		C	
Run		1	2	1	2	1	2	1	2	1	2	1	2
Start Demerit													
Idle													
	Good	2											
Rough/Surge	Light			1	2	1	1		1	2	3	3	2
	Heavy		3	6	6	3	3	3		3			
Stalls		4				4	4		4			4	
Idle													
During Cycle		1		3		7	8	1				5	1
Acceleration													
	Good												
Rough/Stumble	Light	2	2	3		3	4	1	3		1	5	4
	Heavy									3	3	3	
Chuggle/Surge	Light												
	Heavy												
Hesitation/Sag	Light		2	2	2	3	3	1		1	1	5	6
	Medium					5							9
	Heavy												
Backfire	Light		2										
	Heavy												
Stalls				12	12								
Interruptions											6		
Road Load													
	Good												
Roughness	Light			2	3		1		1	1	1		
	Heavy												
Chuggle/Surge	Light						1						
	Heavy												
Stalls													
Total		9	10	29	25	26	25	6	9	10	15	25	22

I.D. Campbell/mrp
87 07 02
1304s